Stream Temperature Science, WQ Temperature Standard & TMDLs, and Riparian Management in Forestlands

Informational Item: Environmental Quality Commission Meeting
June 19, 2014

Gene Foster & Josh Seeds: DEQ
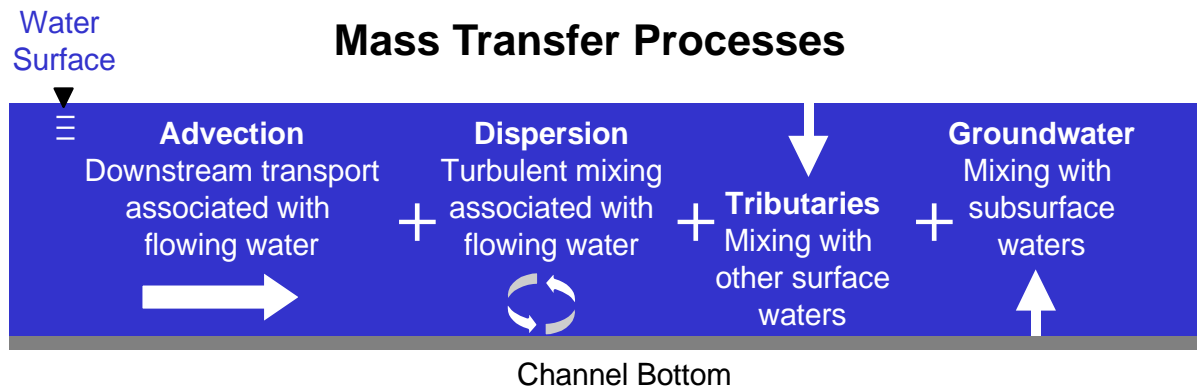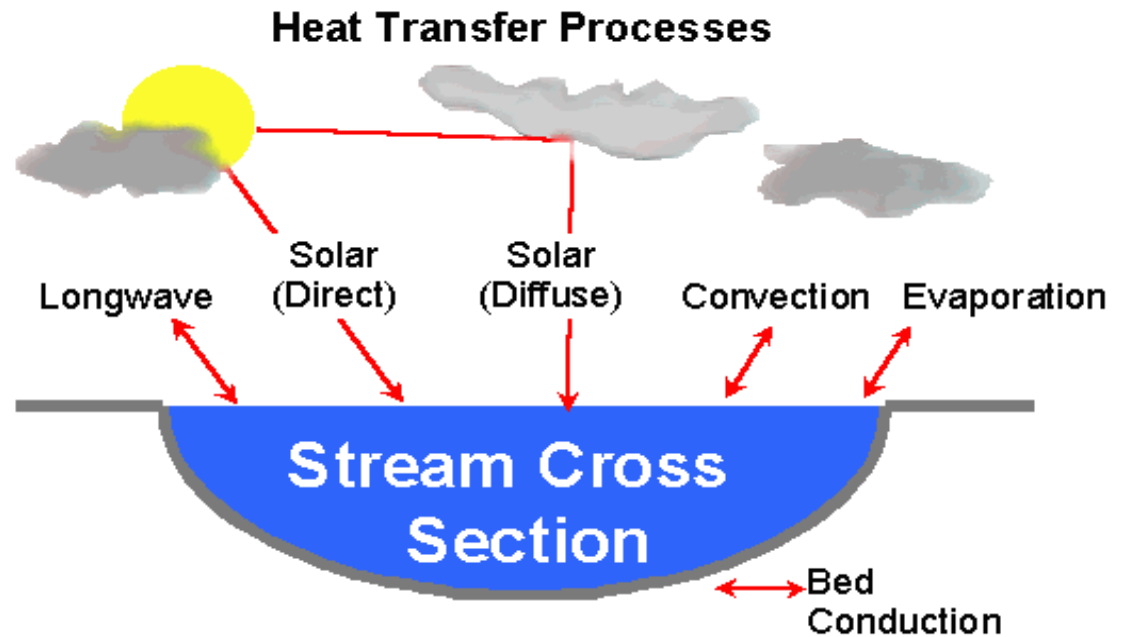**Bruce McIntosh & Dave Jepsen: ODFW**

Presentation Purpose

- Summary of the factors affecting stream temperatures in Oregon

- The importance of stream temperature for aquatic biota

- The rationale for minimizing anthropogenic warming and restoring and protecting natural thermal regime approach used in the temperature standard (including the Protecting Cold Water Criteria)

- Explain how TMDLs are used as a tool to protect aquatic species & restore natural thermal regimes

- Provide information on the connection between temperature standards & forest practices in Oregon & neighboring states.
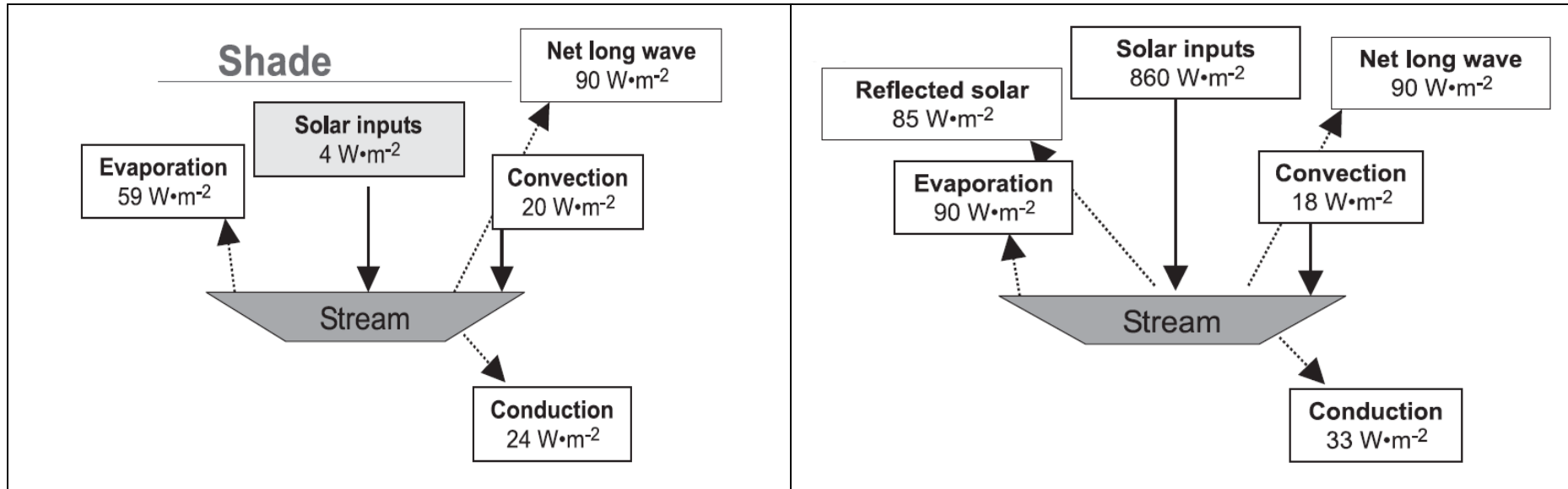
Basics of Stream Temperature

Stream temperatures within watersheds are affected by:

- Heat transfer
- Mass transfer

Heat Transfer Processes

Longwave | Solar (Direct) | Solar (Diffuse) | Convection | Evaporation

Stream Cross Section

Bed Conduction

Water Surface

Mass Transfer Processes

Advection Downstream transport associated with flowing water

+ **Dispersion** Turbulent mixing associated with flowing water

+ **Tributaries** Mixing with other surface waters

+ **Groundwater** Mixing with subsurface waters

Channel Bottom

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Basics of Stream Temperature

Fully shaded:
Thermal energy lost is -149 W*m^{-2}.

Unshaded:
Thermal energy gained is 580 W*m^{-2}.

- Solar energy drives temperature on smaller streams.

- Streams more easily absorb thermal energy from sunlight than lose it once absorbed.

- Dilution of thermal energy is not the same as dissipation.

Johnson 2004

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Basics of Stream Temperature
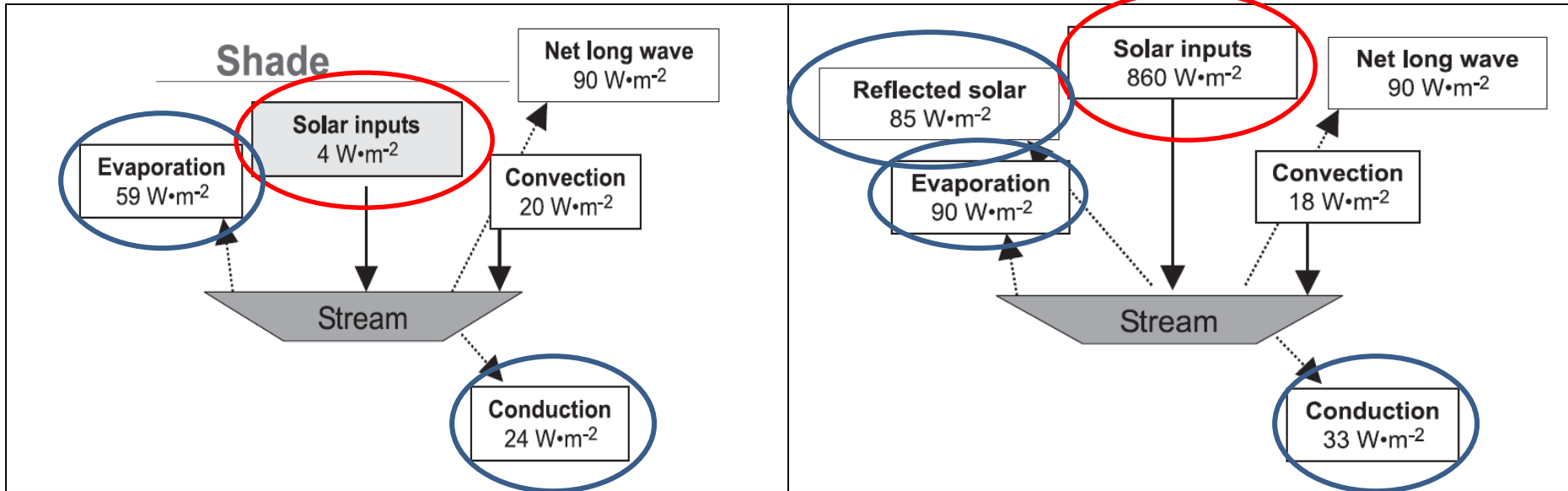

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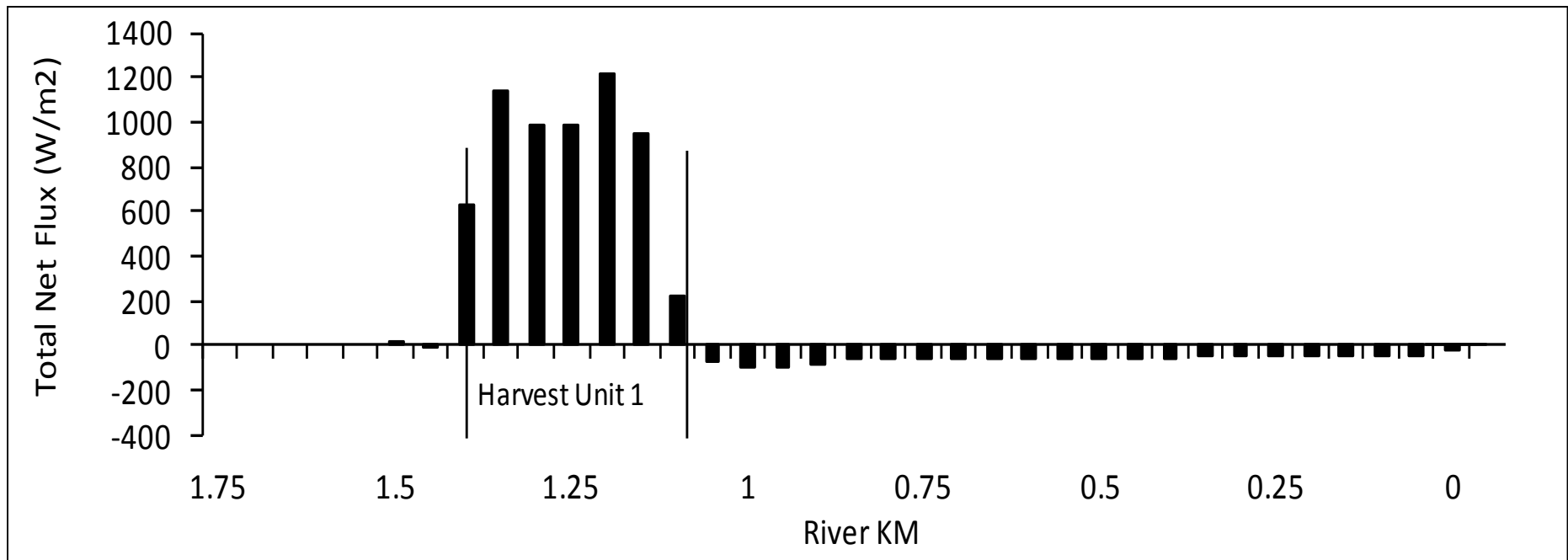

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Johnson 2004

# Harvest Effect on Net Energy Flux in Drift Creek Tributary

- Gain by solar radiation is greater than loss by other fluxes (evaporation, longwave radiation, etc).

Harvest Effect on Stream Temperature in Drift Creek Tributary
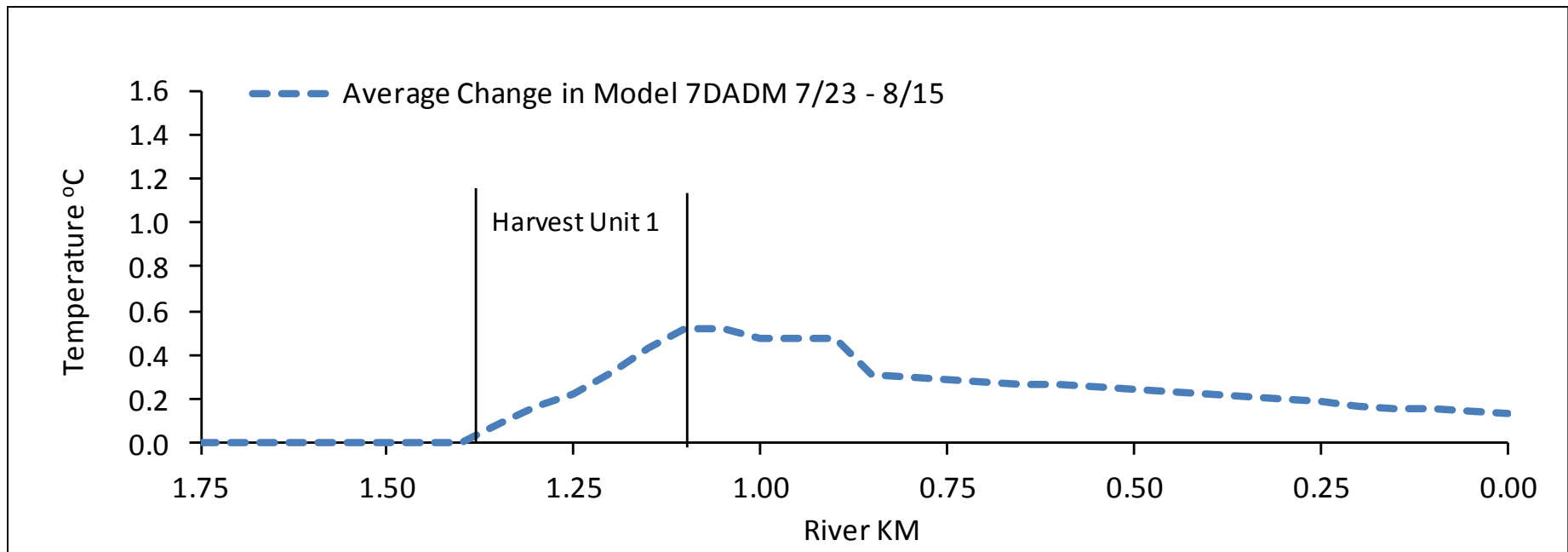
- Since gain is more efficient than loss, thermal energy can be transported downstream.

# Multiple Harvest Effect on Cumulative Warming in Drift Creek Tributary
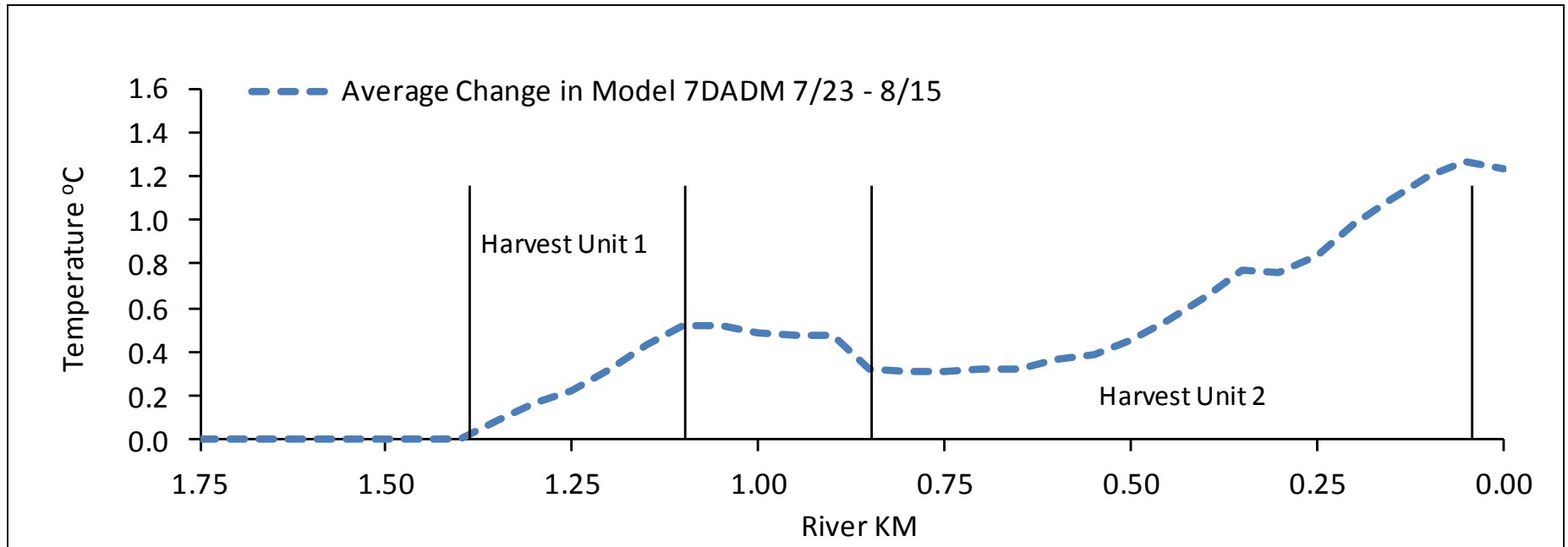
Disturbance on the Landscape

- Riparian disturbances reduce shade & increase stream temperature.

- About 10 years needed for thermal recovery after disturbance.

- Current disturbance regime is different than pre-settlement disturbance regime.

  - Harvest activities occur at a higher rate than natural disturbances.

  - Harvest rotations are substantially shorter than fire return intervals.

  - Important differences between natural disturbances & human disturbances.
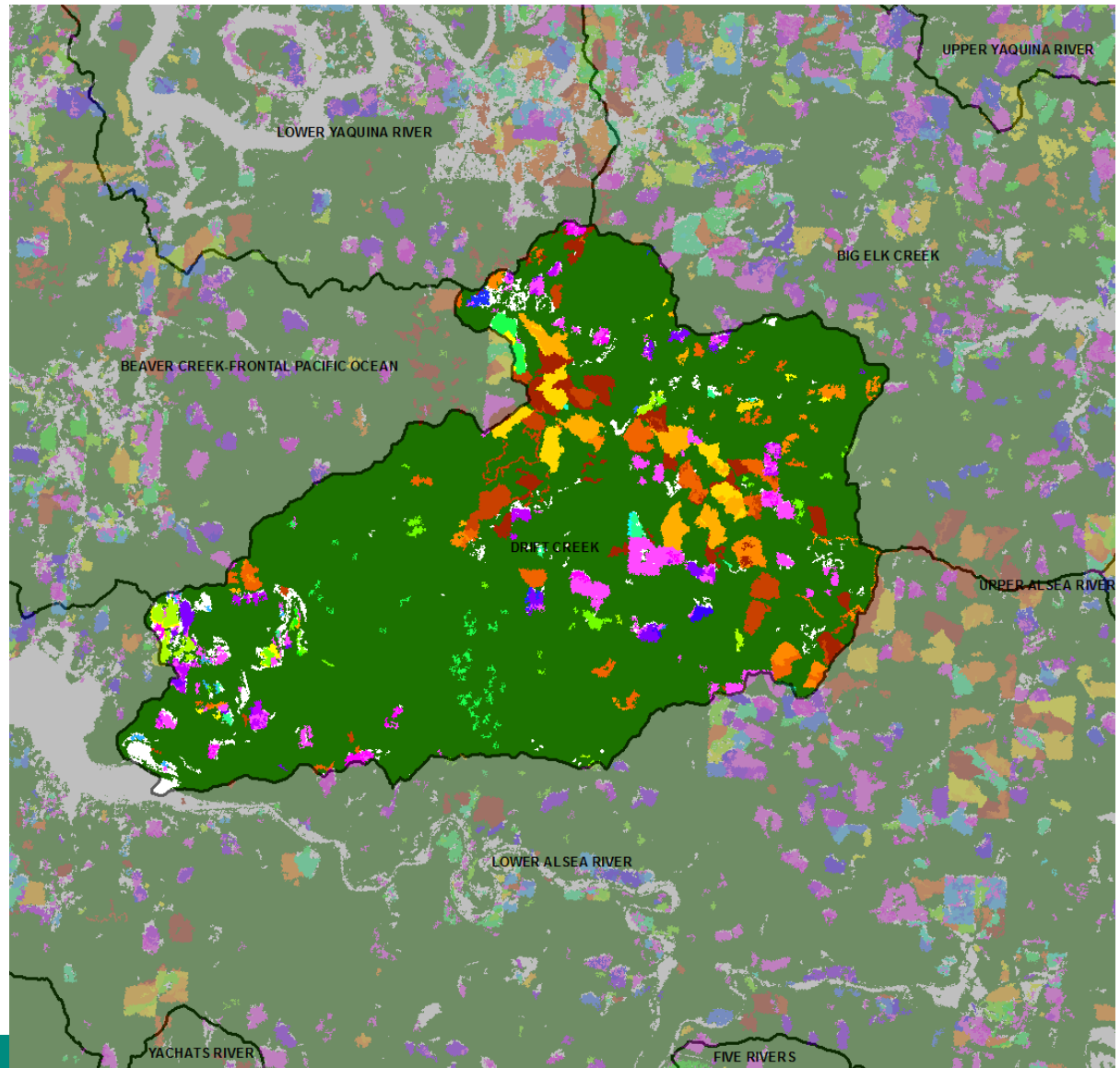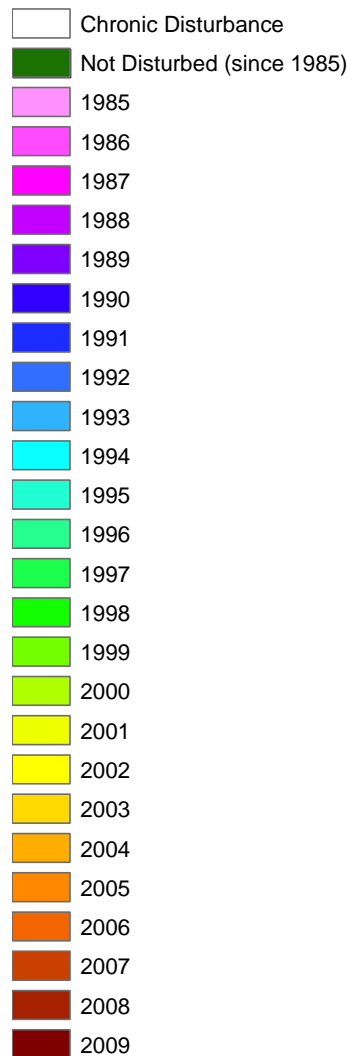
Landscape Disturbance Patterns
Middle Siletz River Watershed
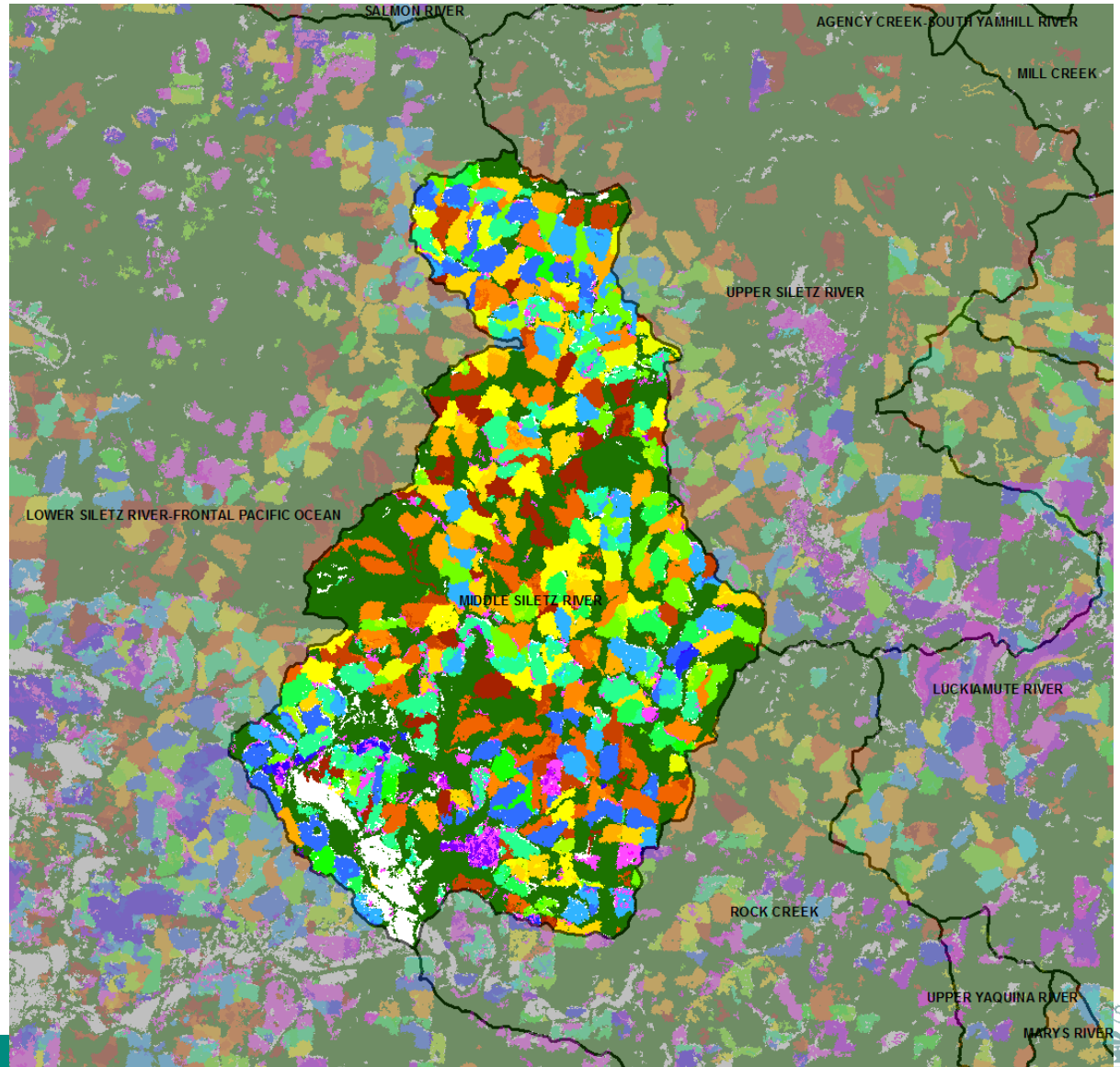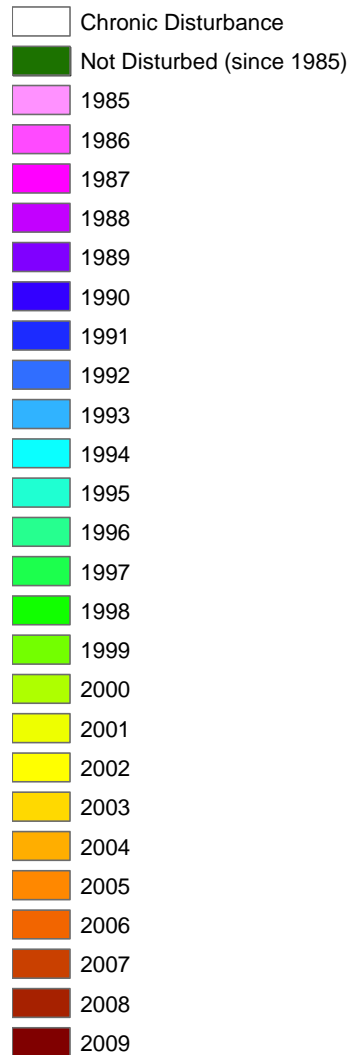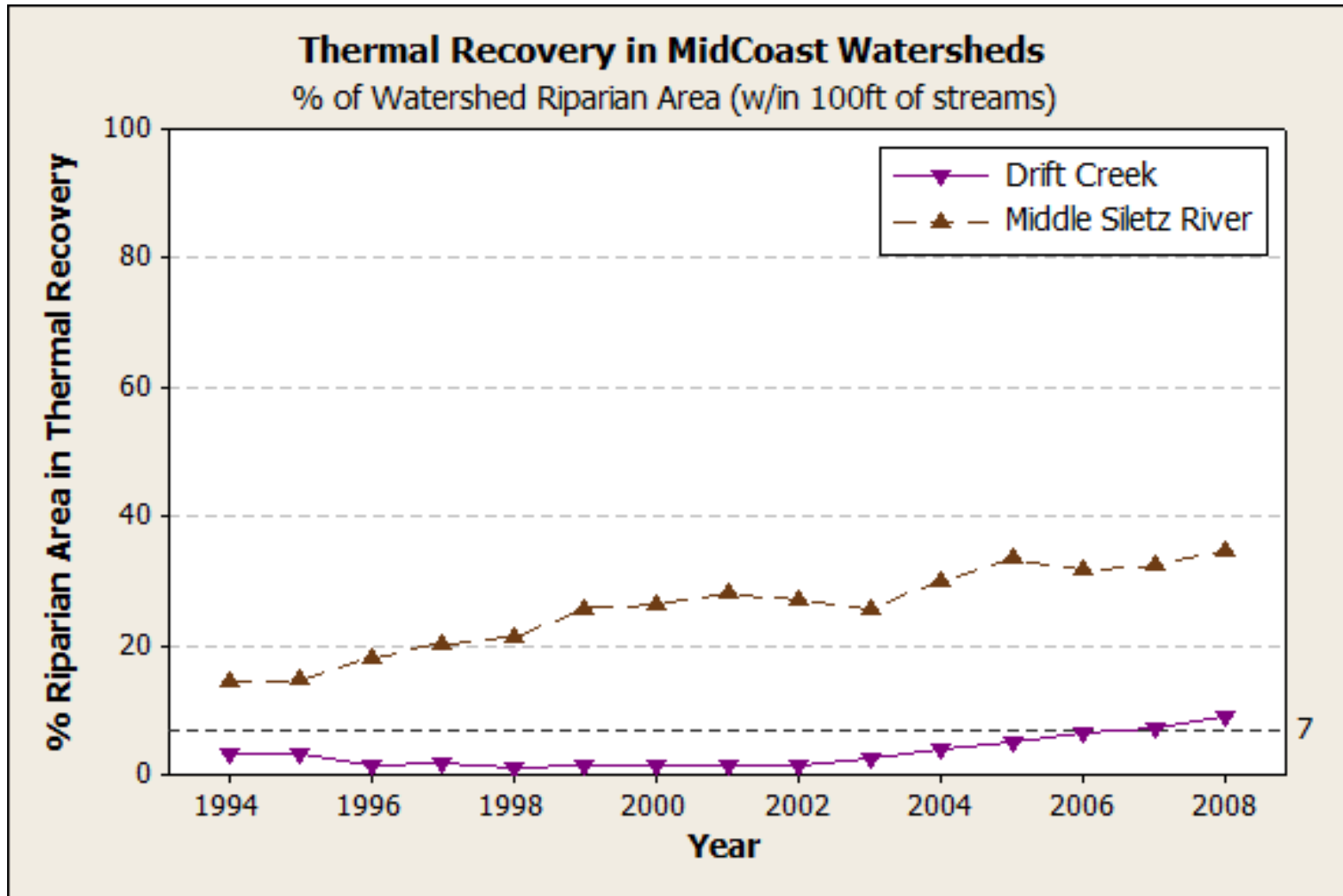
Landscape Disturbance Patterns
Drift Creek Watershed

Riparian Area Disturbance
Middle Siletz River & Drift Creek

Thermal Recovery in MidCoast Watersheds
% of Watershed Riparian Area (w/in 100ft of streams)

Riparian Area Disturbance by Land Use:
Middle Siletz River Watershed

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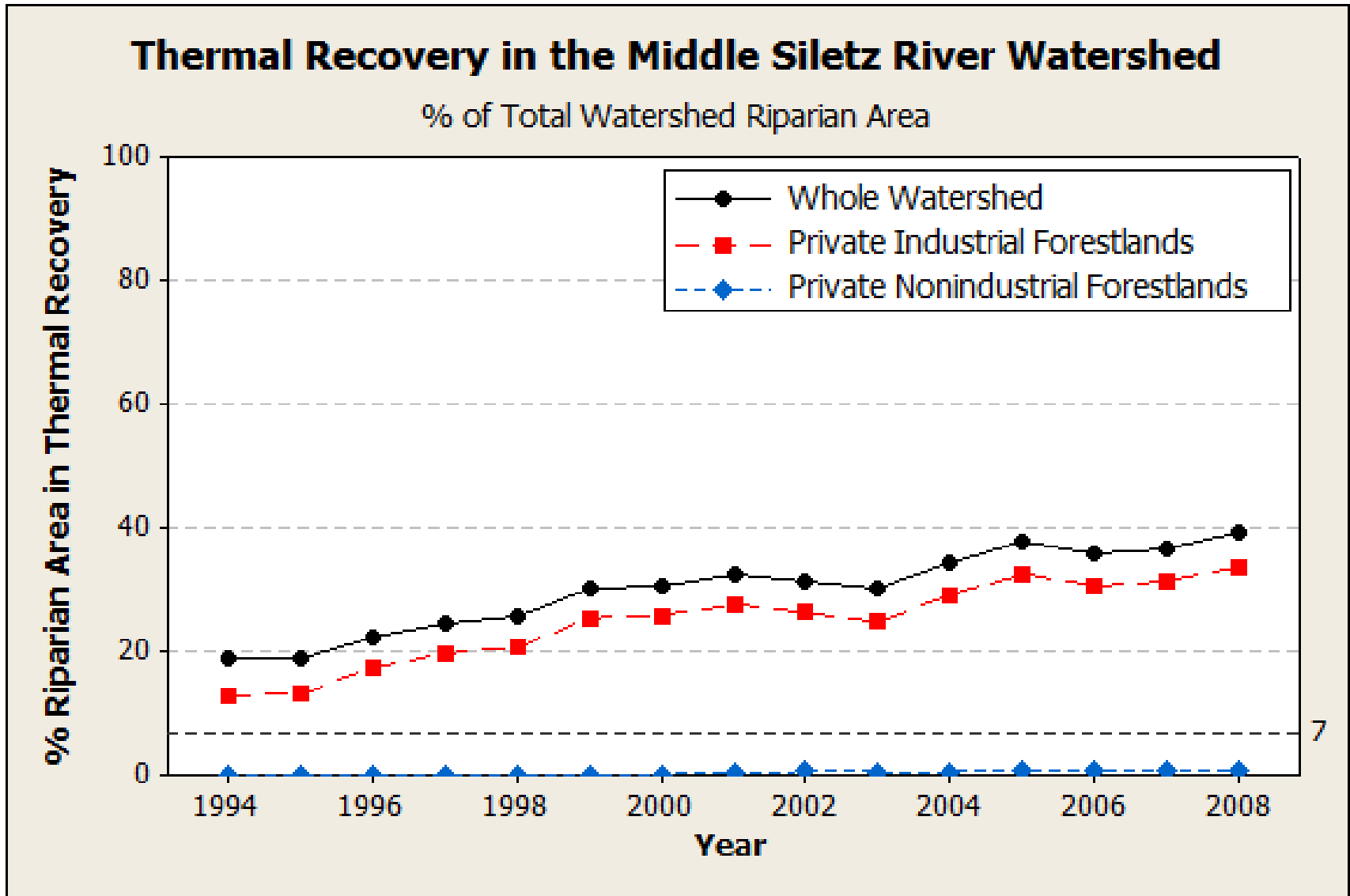
Riparian Area Disturbance by Land Use:
Drift Creek Watershed
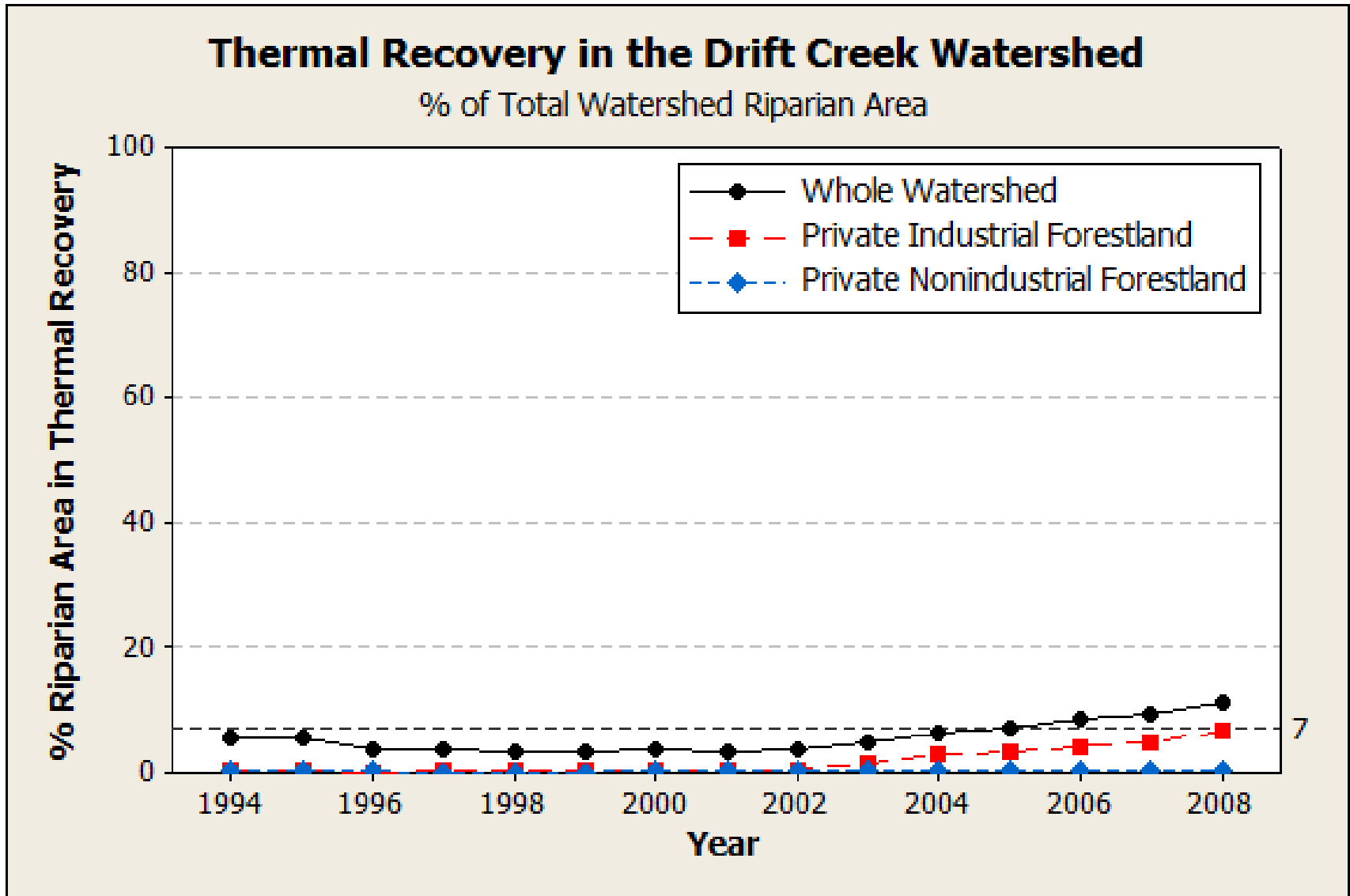
Summary: Downstream Transport of Temperature & Watershed Disturbance Patterns

- Thermal loads can be transported downstream

- Riparian disturbances that reduce shade can increase thermal load to a waterbody

- Multiple riparian disturbances can cause a cumulative increase in temperature downstream

- There are multiple riparian disturbances in watersheds that can cause cumulative increases in temperature

Stream Temperature & Aquatic Life

- Stream temperature influences the rate of ecological & physiological processes.

- Natural thermal regimes provide the best environmental conditions for native aquatic life.

- Temperature effects typically occur on a continuum, but are not linear. Increases above natural thermal potential:

  - Increase physiological risk to fish,

  - Increase extinction risk to salmonid populations, particularly when accrued across the landscape.

- Thermal diversity is necessary at multiple scales.

Natural Thermal Regimes

Water temperature (°C)
- ● < 12
- ● 12-14
- ● 14-16
- ● 16-18
- ● 18-20
- ● >20

20 km
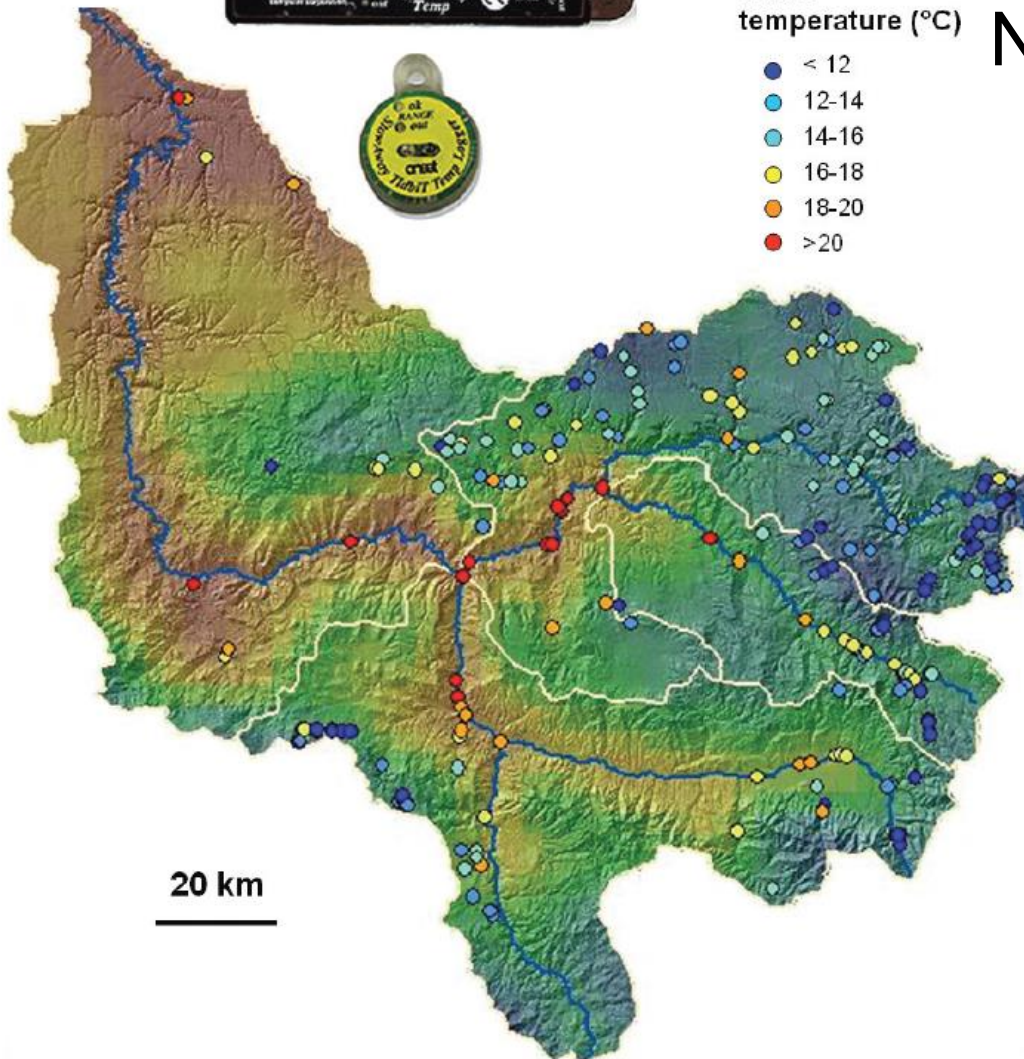
Natural thermal regimes are part of habitat complexity.

– Stream temperature is naturally variable.

– Landscape alteration changes the behavior of stream temperature.

– Fish life histories are linked to seasonal variability, promoting locally adapted populations.

Torgersen et al 2012

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Loss of Stream Temperature Diversity
(including cold water)

- Reduces life history expression, local adaptation, & variation among populations.

- Reduces diversity in fish populations.

- Therefore, reduces population & meta-population resilience.

Torgersen et al 2012

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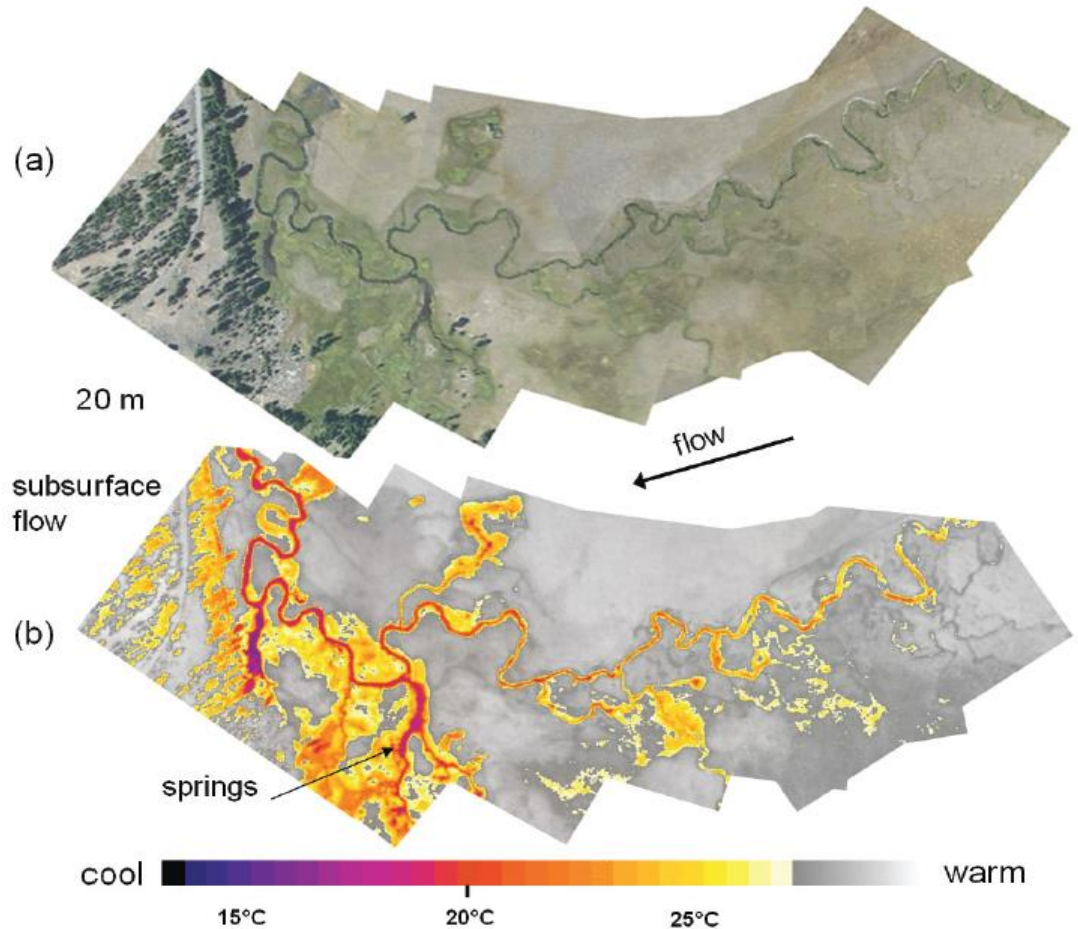
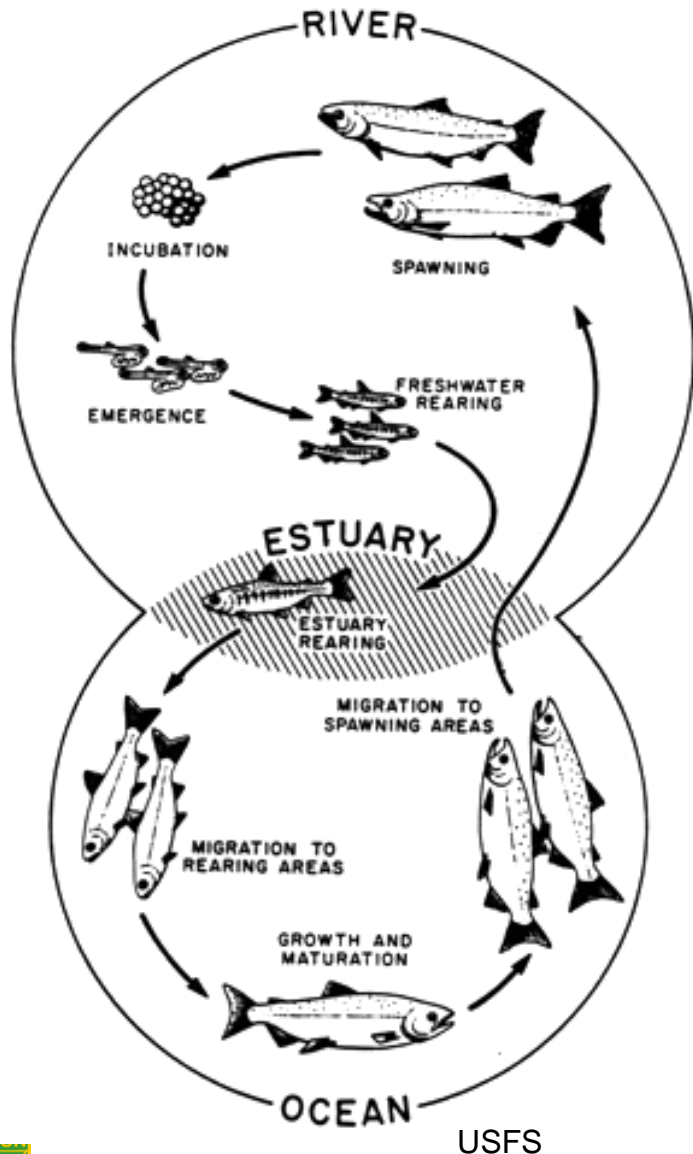# Thermal Diversity & Biological Productivity

RIVER

INCUBATION

SPAWNING

EMERGENCE

FRESHWATER REARING

ESTUARY

ESTUARY REARING

MIGRATION TO SPAWNING AREAS

MIGRATION TO REARING AREAS

GROWTH AND MATURATION

OCEAN

USFS

- Population productivity in freshwater is linked to temperature variability including colder waters.

  – Determines metabolic rates of fish & other aquatic ectotherms.

  – Fish exploit thermal variability to avoid heat stress & to meet metabolic & reproductive needs.

  – Coho exploiting thermal heterogeneity grow faster than individuals with other behaviors.

Temporal & Spatial Refuges

- A network of thermal refuges allows greater use of the overall stream network.

- Species with colder thermal requirements (e.g. bull trout) are confined to cold-water refuges.
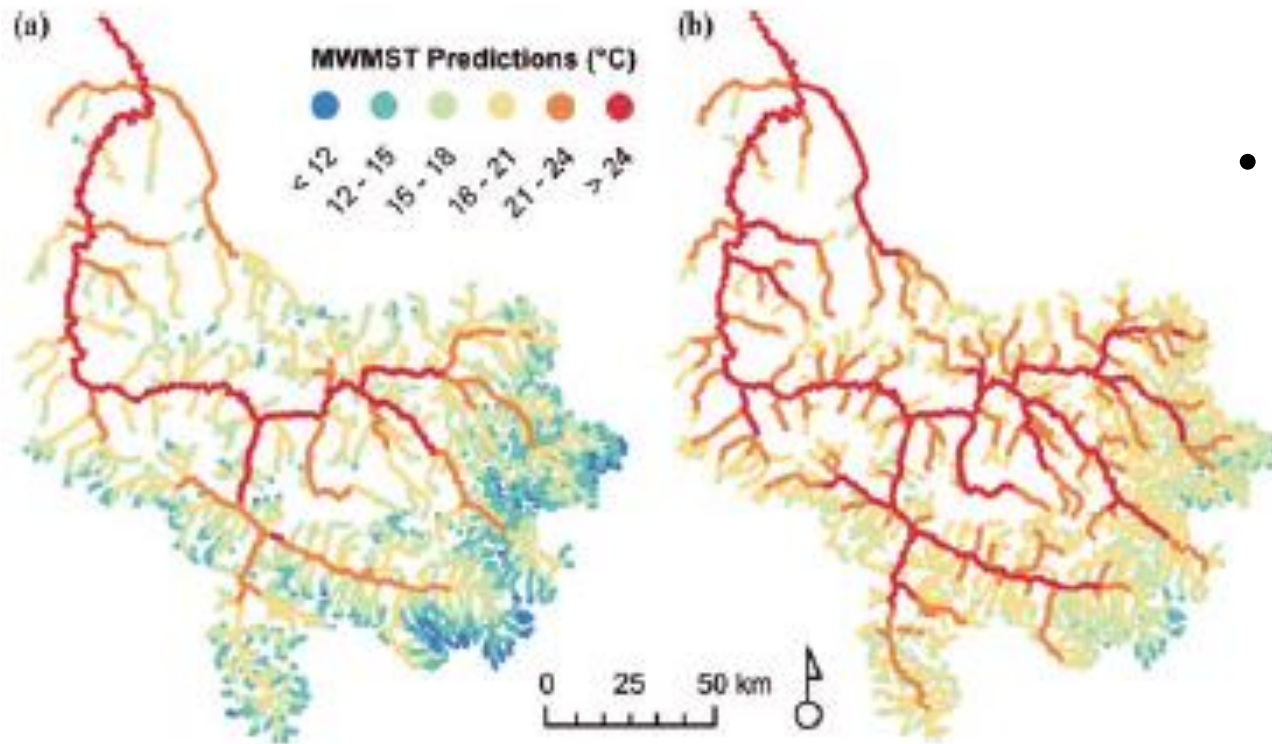
- With climate change, current cold waters <u>will be</u> the future thermal refuges.

Ruesch et al 2012

Relevant Oregon Water Quality Standards for Managing Temperature

- <u>Temperature Standard</u>:

    Minimize anthropogenic warming;

    Maintain & restore natural thermal regimes across landscape for all aquatic species.

    - Biologically-Based Numeric Criteria
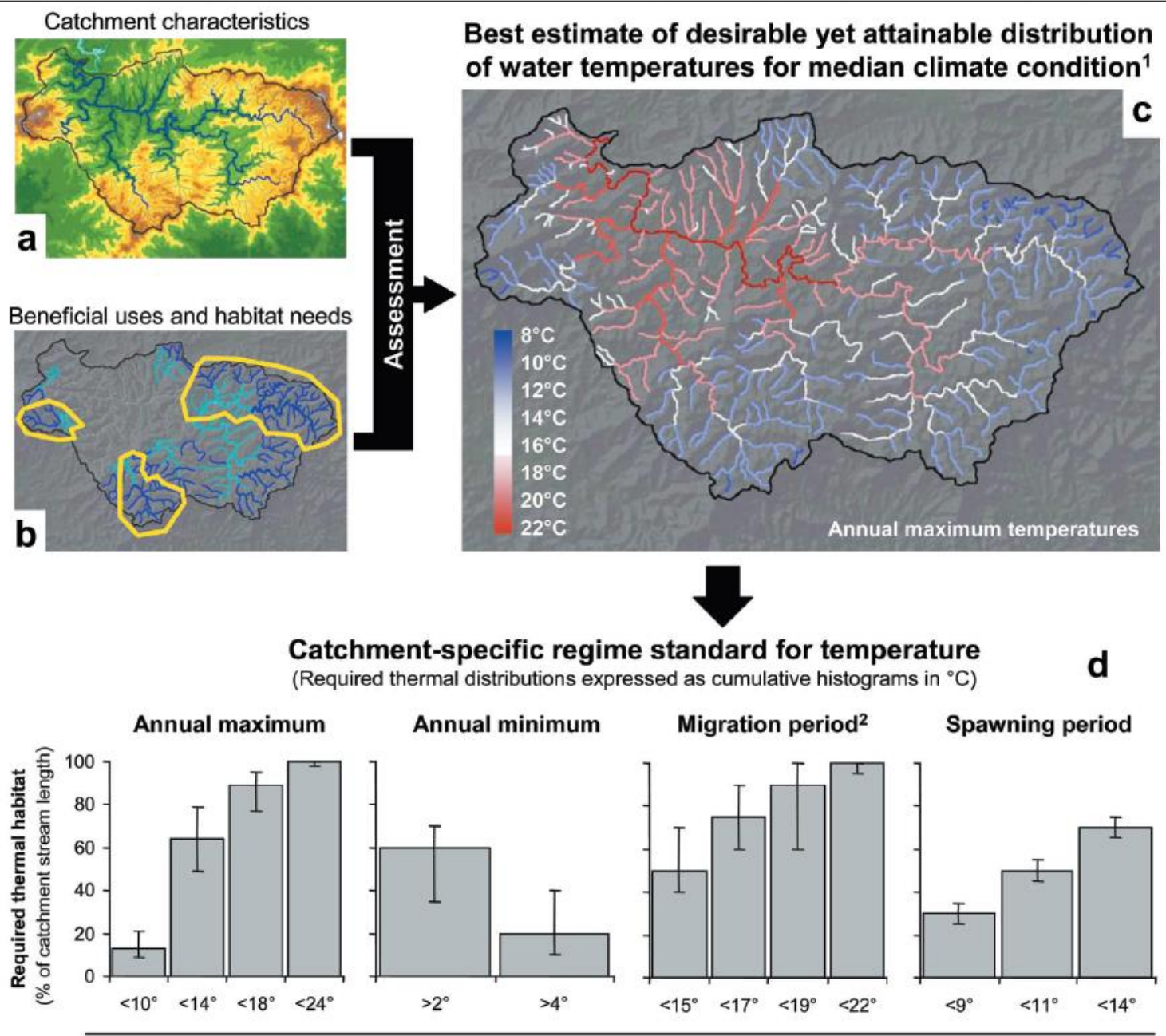
    - Protecting Cold Water criterion

    - Human Use Allowance

- <u>Antidegradation Policy</u>

- <u>Designated Uses</u>

Protecting Cold Water Criterion

• Protects the natural thermal regime in waters colder than the numeric criteria.

Catchment characteristics

a

Beneficial uses and habitat needs

b

Assessment

Best estimate of desirable yet attainable distribution of water temperatures for median climate condition[1]

c

8°C
10°C
12°C
14°C
16°C
18°C
20°C
22°C

Annual maximum temperatures

Catchment-specific regime standard for temperature
(Required thermal distributions expressed as cumulative histograms in °C)

d

Required thermal habitat (% of catchment stream length)

Annual maximum
<10° <14° <18° <24°

Annual minimum
>2° >4°

Migration period[2]
<15° <17° <19° <22°

Spawning period
<9° <11° <14°

Temperature
Total Maximum Daily Loads

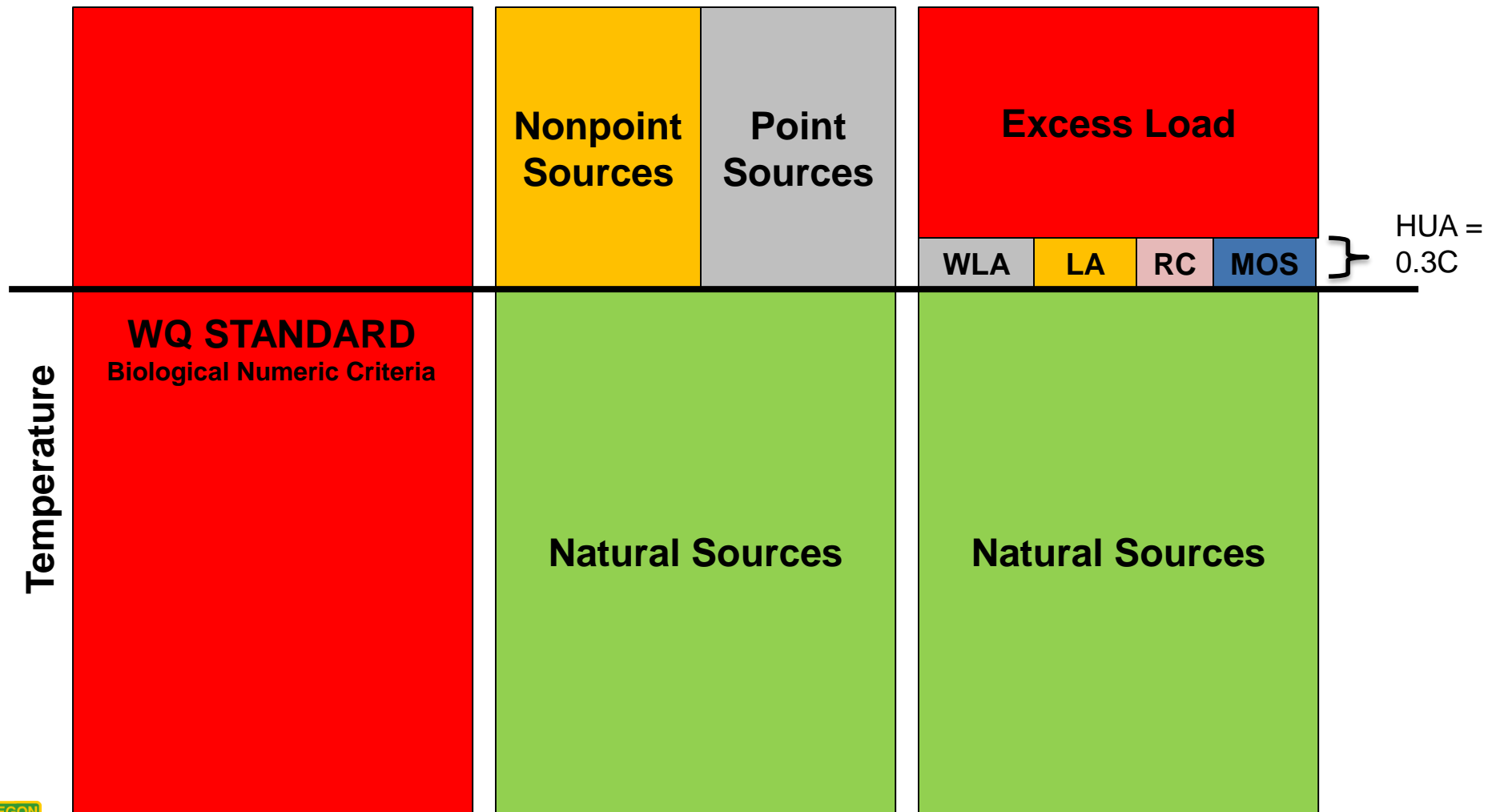•TMDLs are a regulatory tool under the Clean Water Act to protect aquatic species & restore natural thermal regimes.

•Human Use Allowance: 0.3°C for all human sources of thermal loading.

•Human sources are given portions of the HUA as wasteload allocations (point sources) or load allocations (nonpoint sources).

TMDL = WLA + LA + MOS + RC + NS

Current Conditions 303(d) list	Development of TMDL/WQMP	Issuance of TMDL/WQMP

Current Conditions 303(d) list

WQ STANDARD
Biological Numeric Criteria

Development of TMDL/WQMP

Nonpoint Sources | Point Sources

Natural Sources

Issuance of TMDL/WQMP

Excess Load

WLA | LA | RC | MOS

HUA = 0.3C

Natural Sources

Temperature

Willamette Temperature TMDL

Willamette River - Impact of anthropogenic solar radiation loads - Jun 15 to Sep 15, 2001
(loads w/ system potential shade vs. loads w/ current shade)
Current vegetation (Sim 1) minus system potential vegetation (Sim 21)
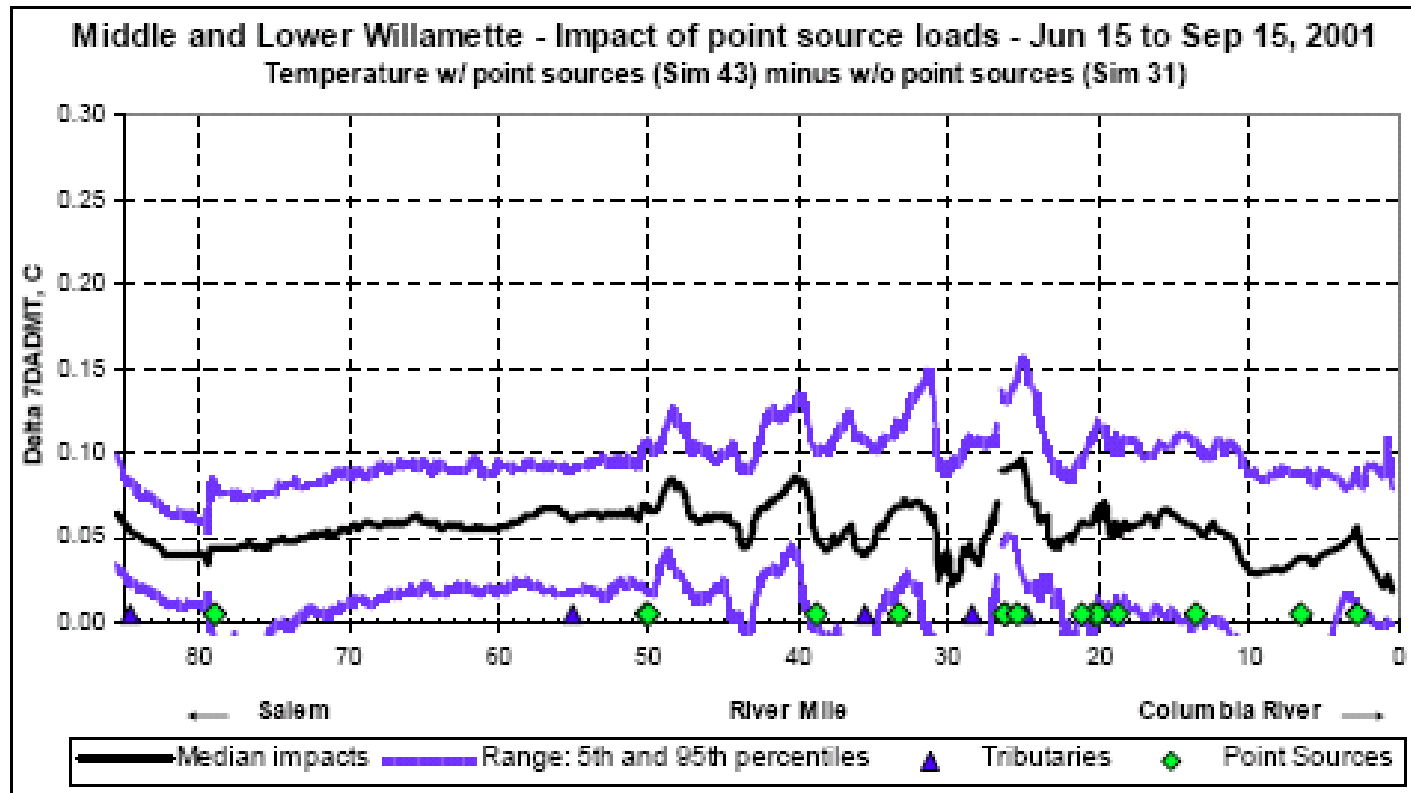
- Nonpoint Source Impacts = Tenths of degrees

- Lack of shade is a larger source of heat than point sources for the mainstem Willamette

Willamette Temperature TMDL

Middle and Lower Willamette - Impact of point source loads - Jun 15 to Sep 15, 2001
Temperature w/ point sources (Sim 43) minus w/o point sources (Sim 31)

- Point Source Impacts = Hundredths of degrees
- Thermal effect from point sources are less than from nonpoint sources
- City of Wilsonville recently spent $300K on cooling towers to meet their WLA of 0.0029C

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Load Allocations for Temperature in Western Oregon TMDLs

•Temperature load allocations range from 0°C to 0.14°C

•DEQ expects that measures to meet TMDL load allocations would also meet the Protecting Cold Water Criterion
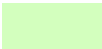
6/10/2014
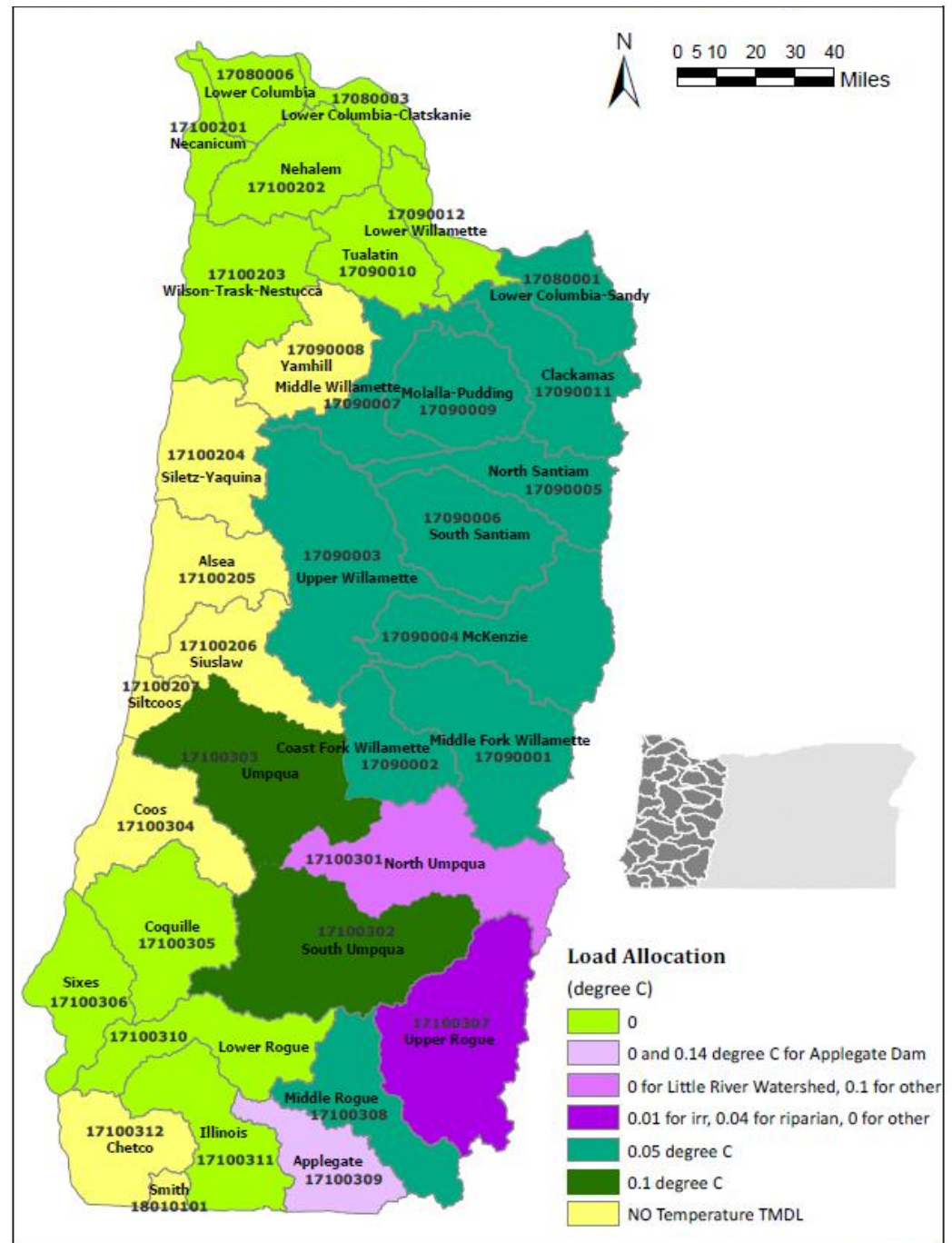
TMDL Development for Temperature Impairments in the MidCoast

- 350+ data stations analyzed (1999 – 2011)

- 200+ stations exceed water quality standards

- 48+ streams identified as impaired - 303(d) list
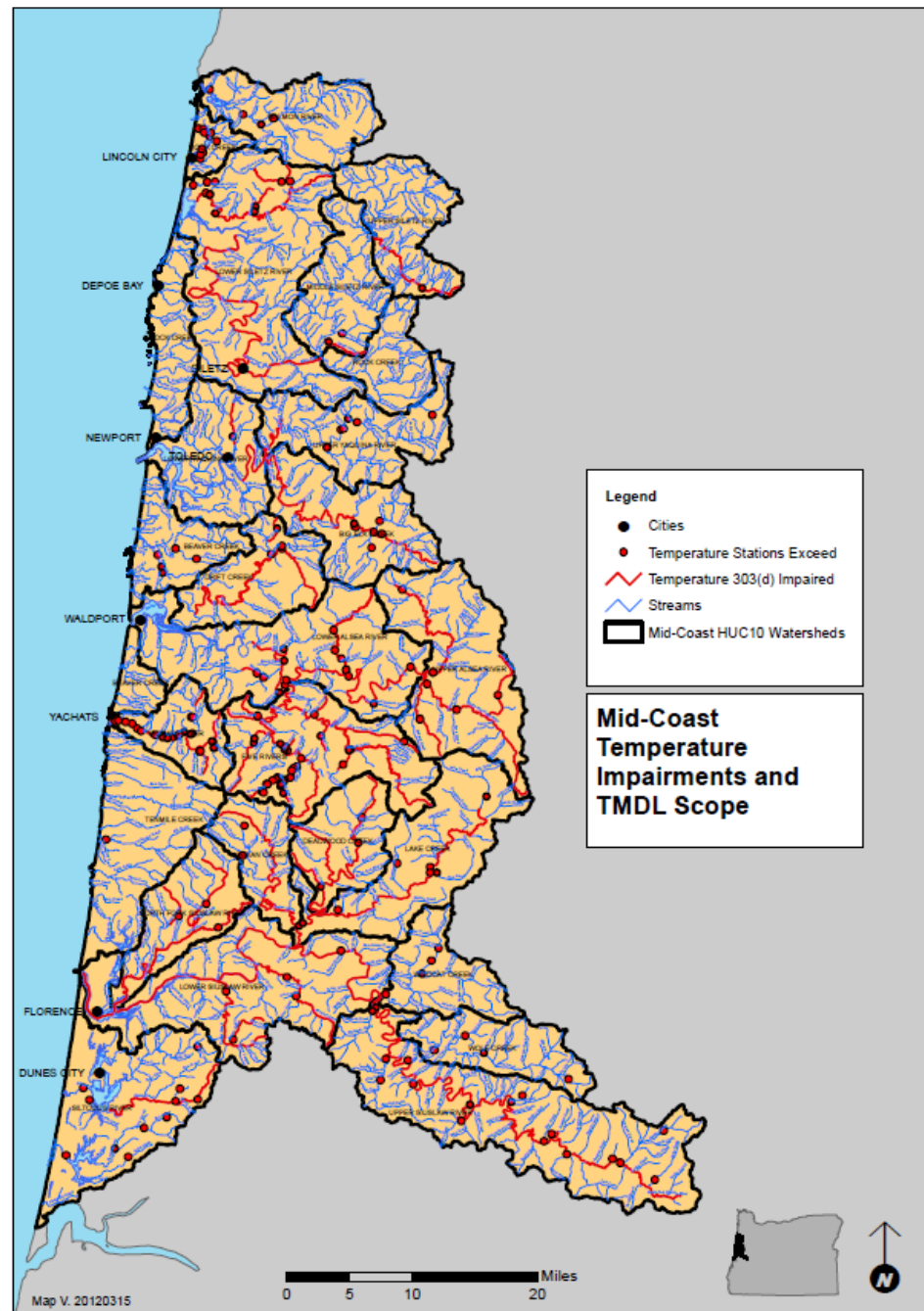
Mapping Riparian Areas & DMAs

DMA

- City of Siletz
- Lincoln County
- ODA
- ODF-PRIVATE-I
- ODF-PRIVATE-NI
- ODOT
- USA-USFS
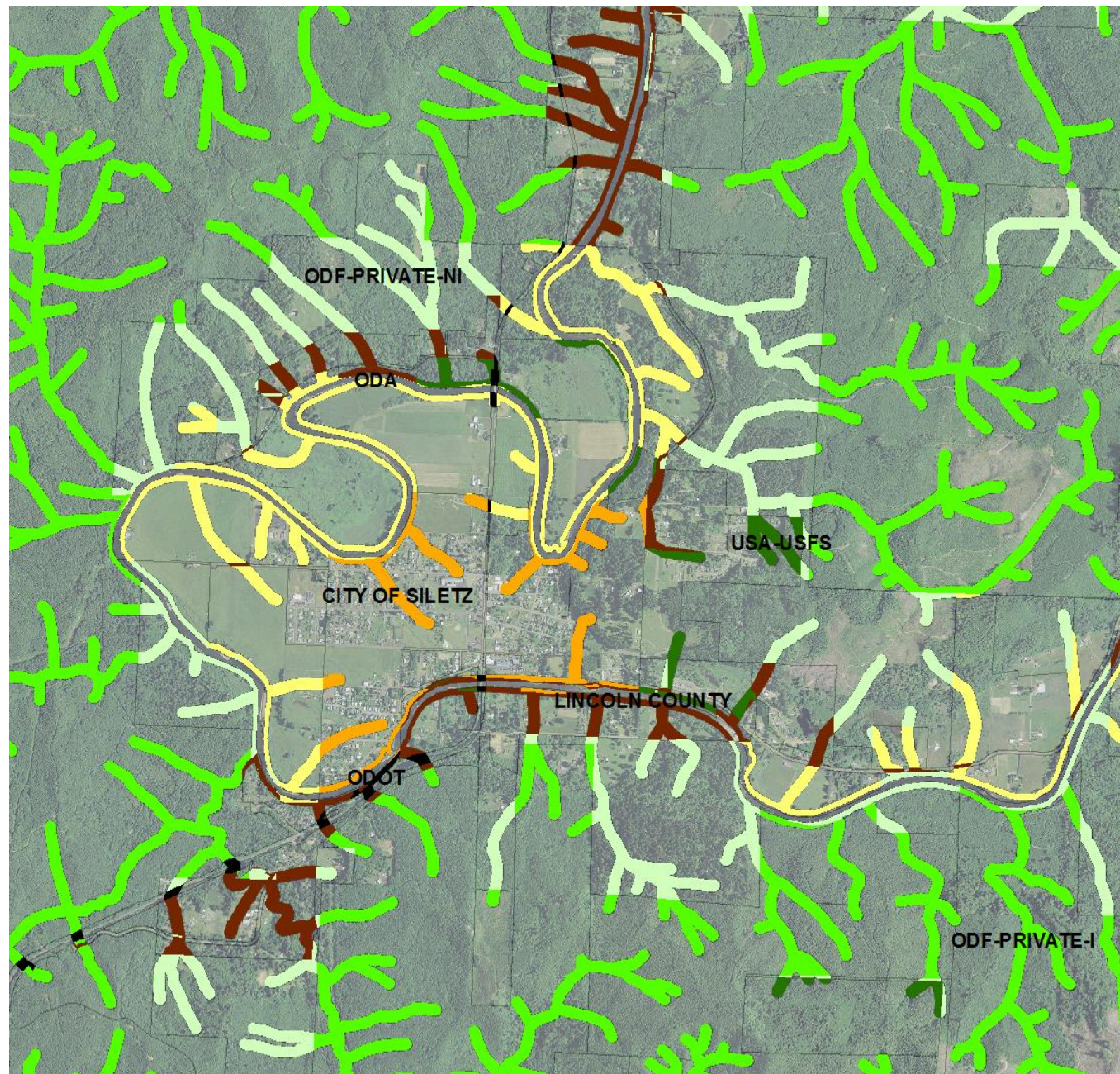
Quantifying Riparian Condition

Vegetation Inventory

- Quantify riparian vegetation condition

- Identify areas that are sources of thermal load

Identify DMA responsibility

- Prioritization of restoration

Quantified Riparian Condition
Big Elk Creek vegetation height by DMA

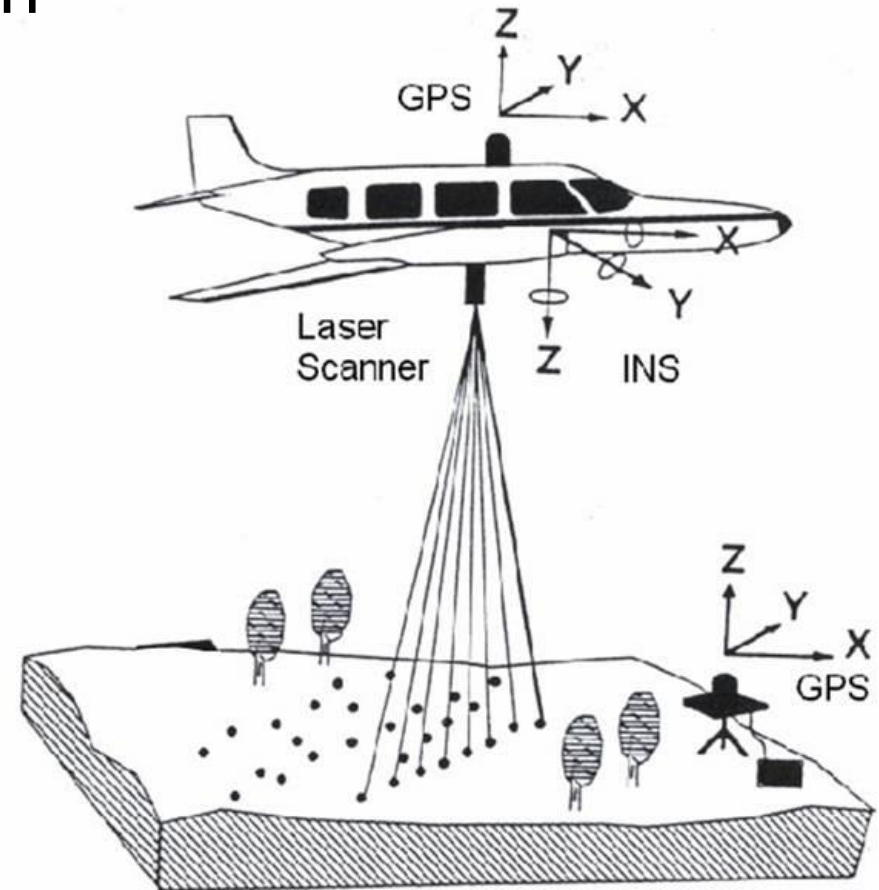Legend: ■ 0 feet ■ 1-5 feet ■ 6-19 feet ■ 20-119 feet ■ 120+ feet

Y-axis: Acres (Log Scale)

Lincoln County: 6, 3, 4, 6
OR-DSL: 4, 18, 66, 306, 52
OR-ODA: 161, 130, 151, 430, 11
OR-ODF: 188, 414, 964, 5,057, 204
USA-BLM: 4, 17, 2
USA-USFS: 27, 100, 573, 2,952, 711
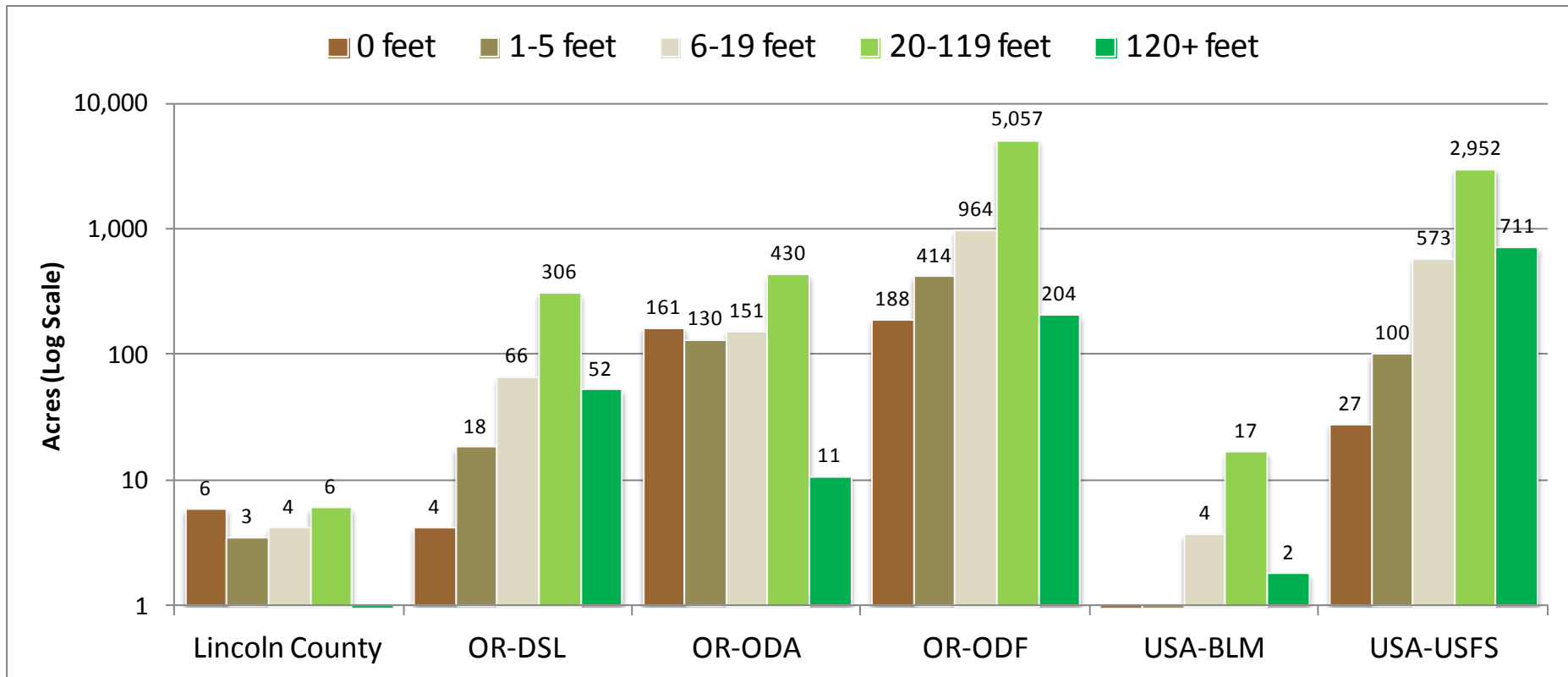
Riparian condition w/in 30m of Big Elk Creek quantified by using LiDAR

Protecting Cold Water in Adjacent States

Washington:

- No warming >2.8°C allowed for <u>all nonpoint sources combined</u> according to the temperature rule.

- Antidegradation policy & numeric criteria must be met.

  - >0.3°C increase in temperature is considered lowering water quality, requiring an antidegradation review.

- Forest practice sufficiency is measured against the >0.3°C increase threshold for <u>all</u> streams.

- Forest practice rules manage for habitat, require maintenance of shade & sediment filtration.

Protecting Cold Water in Adjacent States

California (North Coast):

- Stream temperatures cannot be altered unless alteration does not adversely affect beneficial uses; *and*

- Stream temperature cannot be increased by more than 5°F (2.8°C) above natural temperature; *and*

- The North Coast Region Temperature Policy requires maintaining or achieving "site-specific potential effective shade" in riparian areas on private lands.

- Forest practice rules manage for shade, sediment retention, & habitat.

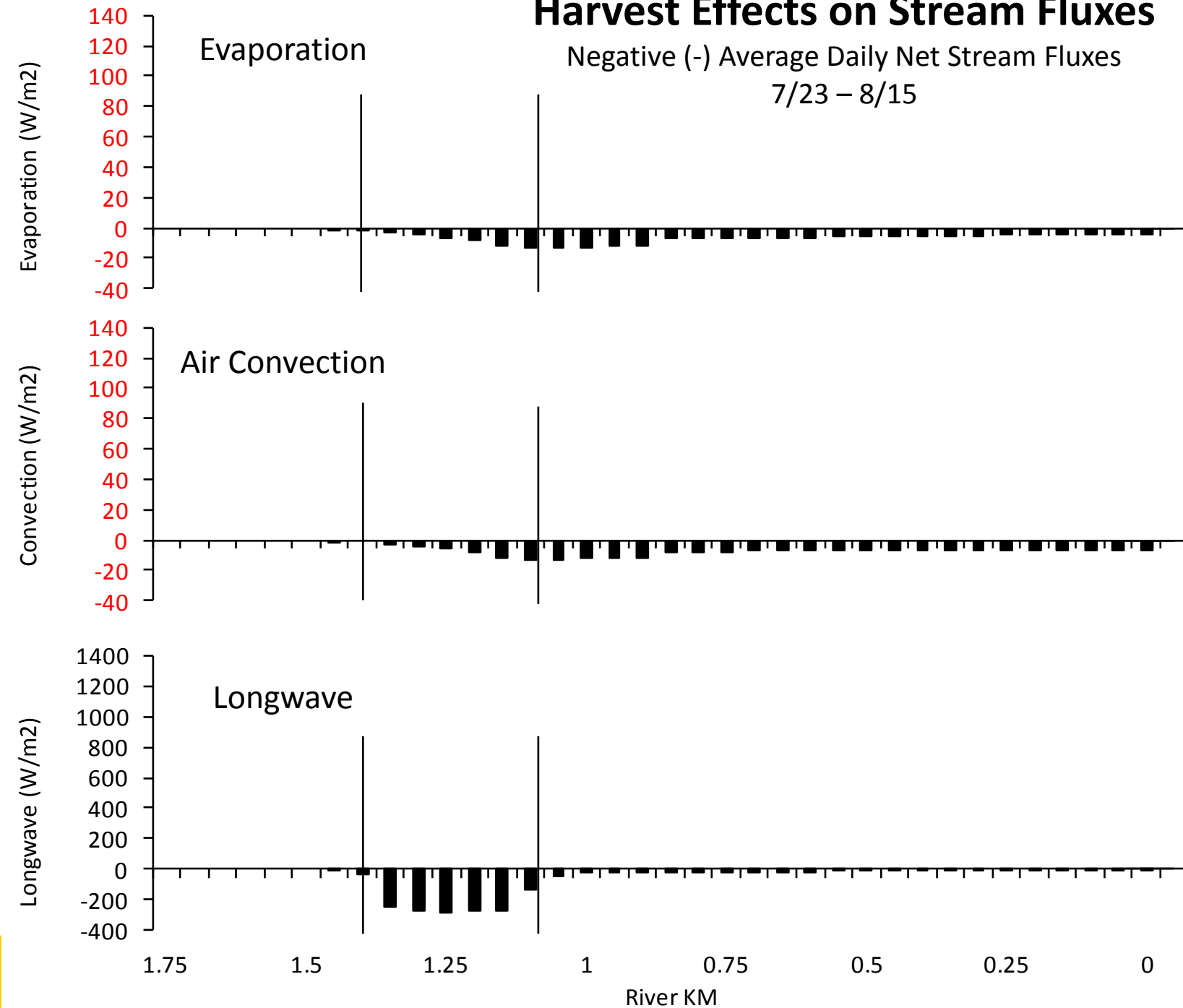# Questions?

Heat Source Results for Argue Creek
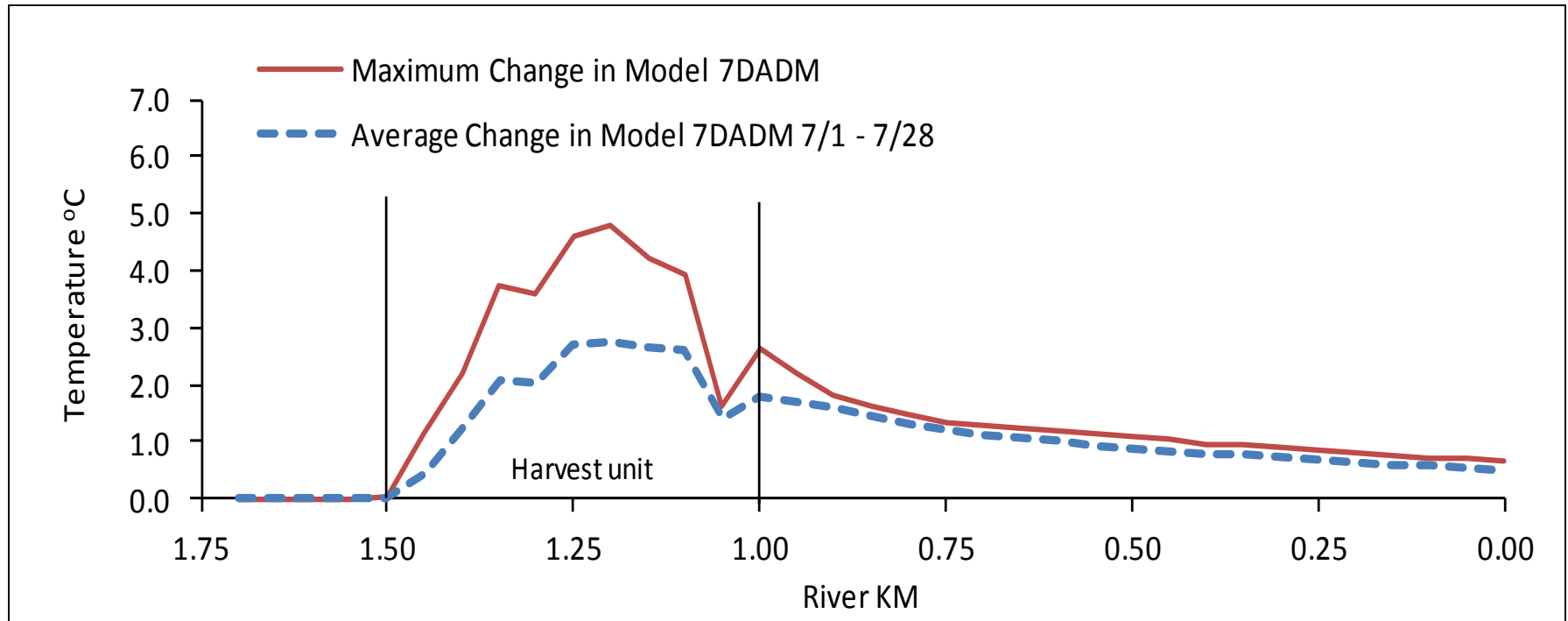
Simulated change in longitudinal 7-day average daily maximum (7DADM) temperatures from harvest at RipStream site 7854, holding all factors constant except vegetation.

Harvest Effects on Stream Fluxes

Negative (-) Average Daily Net Stream Fluxes
7/23 – 8/15

Evaporation

Evaporation (W/m2): 140, 120, 100, 80, 60, 40, 20, 0, -20, -40

Air Convection

Convection (W/m2): 140, 120, 100, 80, 60, 40, 20, 0, -20, -40

Longwave

Longwave (W/m2): 1400, 1200, 1000, 800, 600, 400, 200, 0, -200, -400
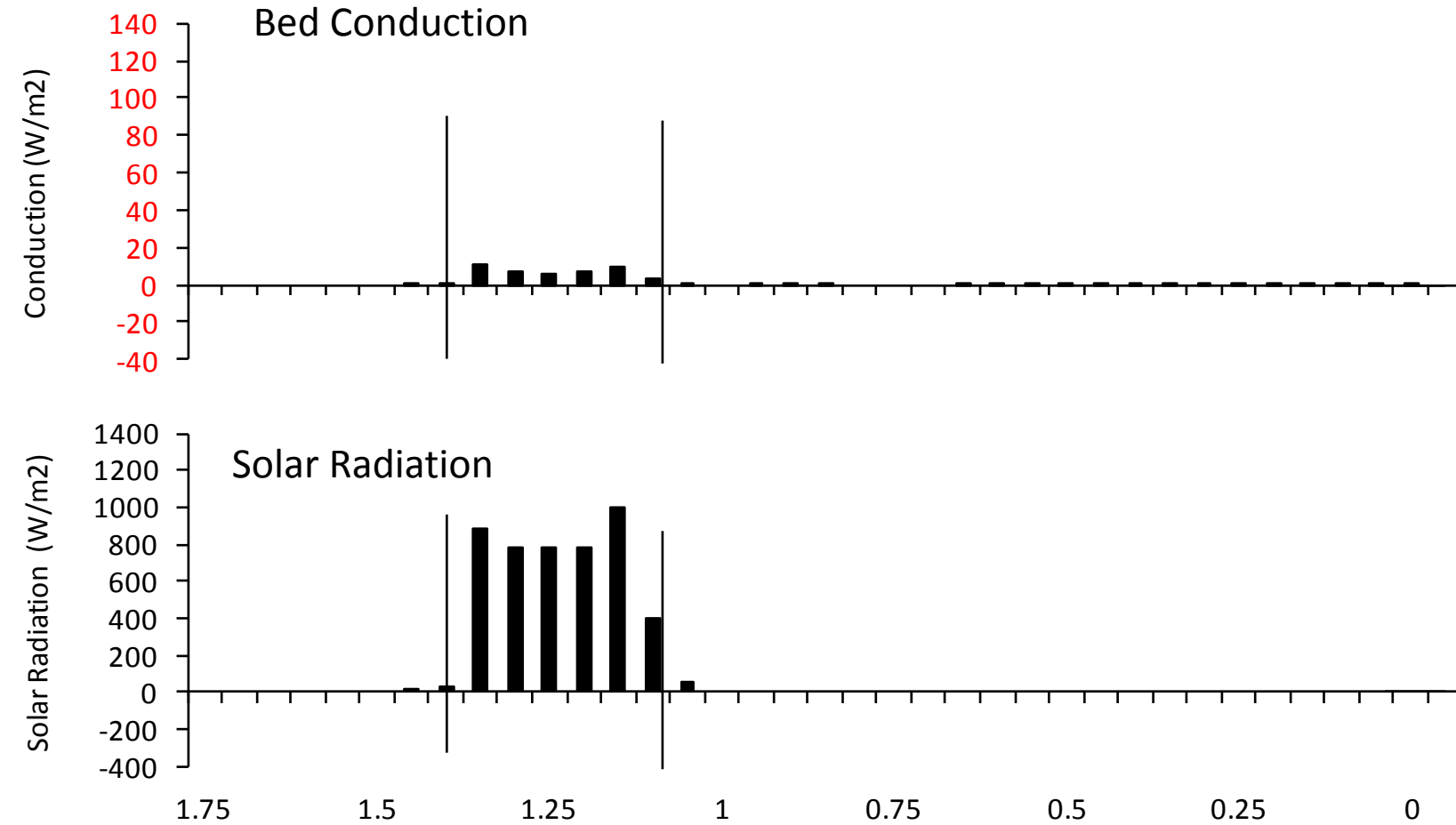
River KM: 1.75, 1.5, 1.25, 1, 0.75, 0.5, 0.25, 0

DEQ

Harvest Effects on Stream Fluxes

Negative (-) Average Daily Net Stream Fluxes
7/23 – 8/15

Oregon Temperature WQS
(OAR 340-041-0028)(2)

Commission's Policy is:

• Protect aquatic ecosystems from adverse warming and cooling caused by anthropogenic activities;

• Minimize the risk to cold-water aquatic ecosystems from anthropogenic warming;

• Encourage the restoration and protection of critical aquatic habitat;

• Control extremes in temperature fluctuations due to anthropogenic activities;

• Minimize additional warming due to anthropogenic sources

Protecting Cold Water Criterion (OAR 340-041-0028(11))

• PCW limits temperature increases to 0.3⁰C in waterbodies colder than the numeric criteria, measured for all sources combined at the point of maximum impact where salmon, steelhead or bull trout are present [OAR …(11)(a)].

•Natural thermal regime provides best conditions for fish.*
•Value in diversity of temperatures, including colder than BBNC.*
•Prevent accumulation of heat in fish-bearing reaches.*
•Retain assimilative capacity for climate variation & climate change.

• Point sources must also limit warming in spawning reaches [OAR …(11)(b)].

• Some waterbodies may also be covered by a temperature TMDL. Meeting TMDL allocations should ensure PCW compliance.

*From Summary of 2003 TAC findings.

Percent area in each LiDAR vegetation height classification within 30 meters of the stream for each DMA in the Big Elk watershed